Name: _____

Class: _____

Due Date: _____

E.2 Quantum Physics

Additional HL Understandings

- The photoelectric effect as evidence of the particle nature of light.
- Photons of a certain frequency, known as the threshold frequency, are required to release photoelectrons from the metal.
- Einstein's explanation using the work function and the maximum kinetic energy of the photoelectrons as given by $E_{\max} = hf - \Phi$ where Φ is the work function of the metal.
- Diffraction of particles as evidence of the wave nature of matter.
- Matter exhibits wave-particle duality.
- The de Broglie wavelength for particles as given by $\lambda = \frac{h}{p}$.
- Compton scattering of light by electrons as additional evidence of the particle nature of light.
- Photons scatter off electrons with increased wavelength.
- The shift in photon wavelength after scattering off an electron as given by $\lambda_{\mathrm{f}} - \lambda_{\mathrm{i}} = \Delta\lambda = \frac{h}{m_{\mathrm{e}}c}(1 - \cos\theta)$.

Additional HL Equations

$$E_{\max} = hf - \Phi$$

$$\lambda = \frac{h}{p}$$

$$\lambda_{\mathrm{f}} - \lambda_{\mathrm{i}} = \Delta\lambda = \frac{h}{m_{\mathrm{e}}c}(1 - \cos\theta)$$

If you are interested in learning more about atomic, quantum, and nuclear physics then please read the book *The Quantum Story: A History in 40 Moments* by Jim Baggott.

Also watch all the videos in this website:
https://www.learner.org/series/physics-for-the-21st-century/

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Use your favorite sources to answer the following questions

1. C: Briefly describe the *photoelectric effect*.

2. C: About how long does it take for the electrons to leave the metal during the photoelectric effect?

3. C: Define *critical/threshold frequency*.

4. C: What will happen to the metal if the intensity of the electromagnetic wave is increased while it is still below the *critical/threshold frequency*? Will the photoelectric effect occur?

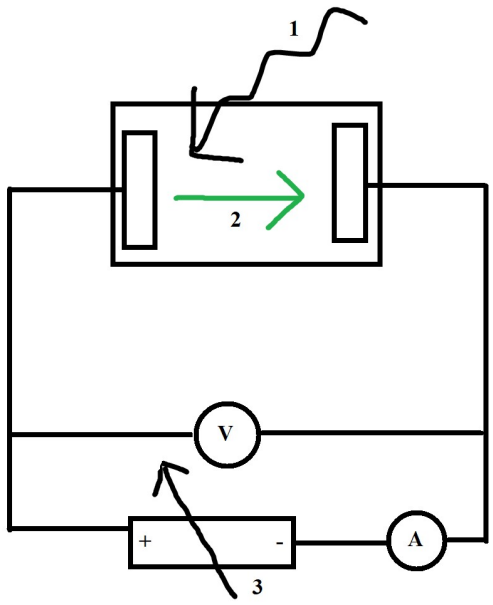
5. C: What will happen to the electrons if the intensity of the electromagnetic wave is increased while it is above the *critical/threshold frequency*?

6. C: What is the *work function* φ?

7. C: Describe the equation given in the IB physics data booklet: $E_{\max} = hf - \varphi$.

8. C: Draw an $E_{\max}$ vs. incoming frequency graph for three metals. What does the horizontal and vertical intercepts tell us? What does the slope tell us?

9. C: Describe, step by step, what is happening in the lab setup below.



Step 1:

Step 2:

Step 3:

10.C: Define *stopping potential/voltage*.

11. C: From the lab setup from question 9 draw a graph of the *current vs. potential difference across the anode and cathode* with the same incoming frequencies and different intensities.

12. C: From the lab setup from question 9 draw a graph of the *current vs. potential difference across the anode and cathode* with different incoming frequencies.

13. C: What is the meaning of *energy is quantized*?

14. C: For the photoelectric effect draw a *current vs. frequency* graph below the threshold frequency and above the threshold frequency with a constant intensity (incoming photons per second) of incoming photons.

15. C: For the photoelectric effect draw two graphs: a *current vs. intensity* graph below the threshold frequency and a *current vs. intensity* graph above the threshold frequency.

16. E: What is the energy content in Joules of a light wave which has a wavelength of 4.40×10^3 Angstroms?

17. E: What will be the energy content in Joules of a light wave which has a frequency of 5.25×10^{14} Hz?

18. E: A light wave has an energy content of 2.93×10^{-19} Joules. What will be the wavelength and frequency of this light wave?

19.E: A photoelectric experiment is performed and data is collected as shown below:

Wavelength (Angstroms)	Stopping Potential (Volts)
4425	1.45
4975	1.13
6200	0.81
7075	0.56

a. Determine the kinetic energies of the emitted photoelectrons in Joules.

Stopping Potential (Volts)	KE (Joules)
1.45	
1.13	
0.81	
0.56	

b. Determine the frequencies of the incoming light waves.

Wavelength (Angstroms)	Wavelength (meters)	Frequency (Hz)
4425		
4975		
6200		
7075		

c. Plot a graph comparing the energies of the emitted photoelectrons to the frequencies of the incoming photons.

d. From your graph calculate an experimental value for Planck's constant.

e. From your graph determine the cut off frequency for this surface and the resulting work function for this surface.

f. Determine the equation describing the kinetic energies of the emitted photoelectrons as a function of the incoming light photons and the work function φ for the surface.

20. E: Light, which has a wavelength of 890. Angstroms, is incident on a photoelectric surface which has a work function (ionization potential) of -13.6 eV.

    a. What is the energy content, in Joules, of this incoming light wave?

    b. How much energy, in Joules, would be required to free the least strongly bound electron from this surface?

    c. What will be the kinetic energy of the emitted photoelectrons?

    d. What will be the velocity of the emitted photoelectrons?

21. E: Light, which has a wavelength of 3.70×10^3 Angstroms, is used to illuminate a photoelectric surface. As a result of this illumination photoelectrons are emitted from the surface. A stopping potential of 1.25 Volts is required to reduce the photocurrent to zero.

    a. What is the maximum kinetic energy of the emitted photoelectrons?

    b. What is the energy content of the incoming photons?

    c. What is the work function of this surface in eV?

22. C: What is the de *Broglie hypothesis*? What is the equation?

23. E: Usain Bolt has a mass of 94.0 kg. He is running with a speed of 10.44 m/s. What is his wavelength?

24. E: An electron, which has a mass of 9.11×10^{-31} kg, is traveling with a speed of 10.44 m/s. What is its wavelength?

25. C: Where can we see particles, such as electrons, diffract? In which experiment do electrons diffract?

26. C: What is the meaning of *wave-particle duality*?

27. C: Describe the *Compton effect*.

28.E: An incoming photon with a wavelength of 6.00×10^{-10} m strikes an electron at rest. The photon rebounds at an angle of 120. degrees to its original direction. Determine the speed and wavelength of the photon after the collision.

29.C: State ***two*** experiments in which light behaves as a wave. Do not explain the experiments, just state them.

30.C: State ***two*** experiments in which light behaves as a particle. Do not explain the experiments, just state them.